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Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring using Hybrid Rule-Based Scheduling and Threshold Control Algorithm

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ABSTRACT

The purpose of this study was to undertake the design and development of an automatic pellet dispenser that has an inbuilt water quality and oxygenation checks that can be used with shrimp aquaculture to solve the challenges of manual feeding, irregular water analysis and inability to control automated aeration levels. The work includes automation of feeding times, monitoring of five important water parameters (dissolved oxygen, pH, water level, temperature, and total dissolved solids) and automatic oxygenation via a hybrid rule-based scheduling and threshold control algorithm on a dual controller system. This system was designed based on a Heltec WiFi LoRa 32 V3 microcontroller to sense the fields and a Raspberry Pi 4 to manage a web server and database. The hybrid rule-based scheduling algorithm was used to calculate feeding times depending on daily schedules and the threshold control algorithm was used to start the aerator when the dissolved oxygen dropped below 4.0 mg/L. The system was rated by 15 shrimp farmers with ZKD Farm in Kiamba, Sarangani Province on a 5-point Likert scale. The analysis resulted to an average weighted mean of 4.29/5.00, which is translated to Strongly Agree. The system developed is a fully automated, efficient, and reliable system to solve the problem of shrimp farming; it lowers the number of individuals to work on the farm, feed efficiency, and maximizes water quality and oxygen concentration. The technology will help in the sustainable production of aquaculture by reducing operational costs and enhancing the survival of shrimps.

INTRODUCTION

Farmers face certain challenges in aquaculture. Among them is that the conditions in the pond can be unreliable. The lack of water quality and correct feeding in the prawn and shrimp breeding activities is likely to cause losses in production. Excess or insufficiency in feeding results in wasting of feed, retarded growth and poor pond environment (Morial, 2024). Water quality is the most crucial aspect in aquaculture. The growth and survival of prawns are directly influenced by dissolved oxygen, pH and temperature. Lack of proper monitoring can lead to the weakness of prawns, sickness, or death in huge numbers (Vicencio *et al.,*, 2025). There is also the issue of aeration, which generally operates continuously and consumes large amounts of power, but prawns' oxygen demands are not well known. Pond oxygen requirements are dynamic with respect to time day of the day, feeding, water quality and the prawn activity. Nevertheless, the traditional systems of aeration are unable to adapt in such a way. This has led to the system being very expensive and inefficient as farmers end up wasting energy in running aerators, yet they still run the risk of lacking oxygen at the time of peak demand (Valerio *et al.,*, 2023). The automatic pellet feeding system can be programmed to give the appropriate amount of food at the appropriate time. In the meantime, there is a water condition and oxygen monitoring system which gives real-time data regarding the status of the ponds (Valencia *et al.,*, 2022). The combination of these techniques leads to less waste of feed, clean water and enough electricity used in aeration. The study will be useful in sustainable aquaculture. It offers a valuable mechanism to the farmers in terms of minimizing production expenses, better management of ponds, and productivity. The researchers came up with the idea after noticing that the traditional pond management involves a lot of manual labor and continuous aeration which is costly yet less efficient. Automation can also provide a fresh solution to the profitability, efficiency, and reliability of aquaculture when it is combined with intelligent monitoring systems (Balaji *et al.,*, 2025).

LITERATURE REVIEW

Related Literature

The modernization and technological advancement in today's era have made the management of aquaculture through the Internet of Things (IoT), artificial intelligence (AI), and renewable energy more efficient than before. The traditional shrimp farming practices include manual feed supply and rare water quality inspection, resulting in overfeeding, poor water quality, and increased mortality rate in shrimps. Due to such factors, there is a need for automated and intelligent systems. Some previous research studies have shown the application of technology to manage aquaculture more efficiently. For instance, Valencia *et al.,* (2022) proposed the construction of an automated fishpond feeder equipped with GSM modules and sensors for assessing water quality, ensuring better feeding accuracy. However, their solution did

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not include the management of oxygenation levels or adaptive algorithm. Similarly, in the assessment of water quality in fishponds in Bulacan, Vicencio *et al.,* (2025) identified oxygen imbalance and the requirement of automated systems. While Morial (2024) designed an automated fish feeder through a mobile scheduling application concentrating only on the fish feeder device, Ylaya *et al.,* (2023) designed an automated fish feeder via a mobile scheduling application that is used to automate the milkfish rearing process. Remote programming was the key point of their research, whereas remote programming combined with water quality sensing will be the core of the current research. In addition, there have been local studies on pond aeration and water quality control systems. In Laguna, Valerio *et al.,* (2023) developed a low-cost pond aerator controller that utilizes Arduino and dissolved oxygen sensors, whereby the aerators automatically start up when the level of dissolved oxygen drops below a certain threshold level. Their results were lower fish stress levels and enhanced pond stability; however, their design lacked pellet feeding and water quality monitoring components. On the other hand, Santos *et al.,* (2021) of De La Salle University conducted research on an automatic water monitoring system in aquaponic applications, improving survival rates of plants and fish but lacking an automated feeding system. Lastly, Villamor *et al.,* (2024) designed a multifunctional pond management system using Arduino in Iloilo, with automated feeding system as well as pH and temperature measurement but without an automatic aeration system. There have been several other foreign contributions as well in finding solutions towards automation in aquaculture. Hossam *et al.,* (2025) conducted research for precision aquaculture using computer vision and IoT techniques to manage fish food in the case of tilapia fish farming. The research used YOLOv8 algorithms for object detection to measure fish length and weight. However, unlike the current research which focuses on simple microcontroller-based sensors, the study was conducted for AI automation and prediction in large scale settings. Rivera *et al.,* (2021) designed an IoT-based aquaculture control solution for tilapia ponds including feeding automation, dissolved oxygen sensing, and water circulation control, while using non-rule-based threshold controls instead. Moreover, Balaji *et al.,* (2025) created a budget-friendly IoT fish farm management system using Arduino and GSM communication techniques, providing 98% availability along with a quick 5 seconds of data reaction time. There are also studies about either the fish feeding mechanisms or the water quality monitoring alone. El Shal *et al.,* (2021) described the prototype development of a fully automatic fish feeding device for tilapia tanks, which operated with 99.9% efficiency at 14 rpm, had no pellets' damage, and decreased labor cost but did not involve water quality monitoring. Similarly, Wibisono and Jayadi (2024) designed an IoT-based catfish pond using NodeMCU consisting of three parameters: DO, pH, and temperature to increase survival rates of fishes, but they failed to automate the feeding process. Medina *et al.,* (2022) proposed an open-source fish farm water quality monitoring buoy using LoRaWAN for transmitting sensor data remotely from distant ponds, but they did not develop automated feeding. Mohamed *et al.,* (2024) designed an IoT-based auto fish feeding system using servo motor technology, RTC timer module, and Firebase connection, however, their research was focused on feeding only. Nayoun *et al.,* (2024) performed experimental research entitled "IoT Precision Fish Farming" by using three sensor technologies (DO, pH, and temperature) connected through NodeMCU ESP8266 and Arduino IoT cloud platform. Khatri *et al.,* (2024) suggested a monitoring system based on IoT, which makes use of edge computing and artificial intelligence techniques with predictive models based on pH, DO, and temperature sensors, which promotes sustainability practices. Another similar study by Shete *et al.,* (2024), which used IoT-based real-time water quality monitoring for tilapia ponds with less than 5% error, focused entirely on water quality monitoring only. Similarly, Teixeira *et al.,* (2021) suggested a monitoring framework using IoT for precision aquaculture with low-cost communication solutions; however, they did not suggest any automation mechanism for feeding. It can be observed from these studies that IoT, along with automation, and the use of various types of sensors can help enhance aquaculture significantly. Nonetheless, most of them either cover monitoring, feeding, or aeration individually. In this context, this paper attempts to integrate feeding, water quality monitoring, and oxygenation using hybrid rule-based scheduling and threshold control algorithm.

Related Studies

Various local research concentrates on enhancing aquaculture processes through the application of IoT and automation. Blancaflor and Baccay (2022) designed the IoT-Biofloc Water Quality Management System, which incorporated dissolved oxygen, pH, and temperature sensors together with automatic feeders in the process of shrimp cultivation. The results indicated that their innovation enhanced survival rates by 10% and improved growth rates by 3.2% as compared to conventional practices, stressing the efficiency of automation within biofloc technology. Abrajano *et al.,* (2024) performed a study on the IoT-Based Water Quality Monitoring System for Off-Grid Communities in the Philippines, employing an Arduino board equipped with pH, turbidity, and temperature sensors along with Wi-Fi and GSM communication technologies for cloud storage. Their invention turned out to be able to provide affordable water quality monitoring powered by solar energy. Francisco *et al.,* (2024) suggested an automatic fish feeder with Arduino Uno for aquariums allowing the programmed delivery of food and enabling more precision in comparison to handfeed yet suggested the implementation of water quality sensors for better fish well-being. The IoT-based modular monitoring device with LoRaWAN was designed by Tolentino *et al.,* (2021) to measure the levels of pH, dissolved oxygen, turbidity, and temperature while actuating aerators. The accuracy of the device is under 2% deviation from BFAR instruments, demonstrating efficiency in terms of monitoring and correct action implementation; however, feeding automation is not considered. Another multi-sensor system for monitoring water quality in aquaculture, proposed by Papolonias *et al.,* (2025), was developed at Mindanao State University and included an Arduino Nano and an ESP32 along with sensors measuring pH, dissolved oxygen, temperature, and conductivity levels. According to field testing results, the proposed system provides high accuracy; however, no feeding automation or oxygenation were discussed. Moreover, Borbon and Lumauag (2024) have developed the data-driven monitoring system for prawn farms at Iloilo Science and Technology University using sensors with Raspberry Pi and providing descriptive analytics to demonstrate higher accuracy, though feeding and oxygenation are excluded. Salazar *et al.,* (2025), proposed an MSU-Marawi automatic feeding and aeration system prototype was designed, using pre-programmed scheduling to feed pellets and aerate to decrease mortality and feeding costs; however, it did not utilize adaptive thresholds that would respond to changes in the environment. A prototype aquaculture monitoring water kit for measuring the level of pH, turbidity, dissolved oxygen, and temperature through multi-sensors, which was found to have highly accurate measurements when tested against the BFAR equipment, was proposed by Calajate *et al.,* (2024); however, the prototype had no provision for integrating feeding and aeration controls. Foreign research provides further knowledge about automation in feeding, water quality sensing, and intelligent control. Dake *et al.,* (2024) presented a research paper titled IoT-Based Fish Feeding and Water Monitoring with ESP32, where they used ESP32 microcontroller along with sensors like pH, TDS, and temperature to construct an automatic feeder which comprises an auger screw drive motor, RTC module, and GSM connectivity. They found their study gave constant feeding along with real-time water conditions. Sohail *et al.,* (2023) suggested a GSM-based smart aquarium monitoring and feeding system with pH maintenance and aeration, utilizing Arduino Mega 2560 with GSM modules to sense the feed levels, temperature, and water quality with the result having a very low Root Mean Square Error value of 0.037. Hridoy *et al.,* (2025) introduced a predictive model for aquatic water conditions through IoT by considering the sensors' data related to temperature, pH, turbidity, and dissolved oxygen with the help of neural networks with TensorFlow. Lindholm-Lehto (2023) did research on the water quality monitoring system in recirculating aquaculture systems. The research pointed out that to monitor water quality, one should pay attention to parameters such as pH, oxygen, turbidity, and nitrogen compounds; however, despite the progress in technologies, the use of manual methods was observed at farms. The study done by Olanubi *et al.,* (2024) involved the design of a water quality management system based on ESP32, GSM, and WhatsApp through the Internet of Things technology. The parameters included pH level, turbidity, and temperature; however, no system for feeding was considered. Chen *et al.,* (2022) presented research on the IoT-based fish farming monitoring system that analyzed parameters such as water level, pH, dissolved oxygen, and temperature, offering continuous monitoring of the parameters in real-time, which was accurate. Nonetheless, they did not include the automation of the feeding process. On the other hand, Lin *et al.,* (2021) carried out research on the wireless multi-sensor IoT system in aquaculture with sensors for pH, dissolved oxygen, electrical conductivity, and temperature sensors using ESP32 Wi-Fi and ThingSpeak visualization, proving the reliability of the system and its easy calibration. Thus, from the local studies, there are significant advancements in the field of monitoring, detecting, or single automation of parameters.

MATERIALS AND METHODS

This system uses dual-controller design where the field controller is a Heltec WiFi LoRa 32 V3 while the central server is a Raspberry Pi 4. Hardware devices included in the system are detailed in Table 1.

Context Diagram

Table 1: Hardware Components

Components	Function
Heltec wifi Lora 32 V3	Data acquisition from field sensors, control of actuators, LoRa communication
Raspberry Pi 4 Model B	Webserver, database management, LoRa gateway operation
Dissolved Oxygen Sensor	Sensor for oxygen level measurement
pH Sensor	Sensor for acidity measurement
Temperature Sensor	Sensor for measuring temperature
TDS Sensor	Sensor for measuring total dissolved solids
Water Level Sensor	Sensor for water level measurement
Ultrasonic Sensor	Sensor for measuring quantity of feed available in the hopper
DC RS550 Motor	Dispenser motor for driving dispenser mechanism
Relay 1 Channel 12V	Control relay for activating aerator

Servo Motor	Controls opening/closing of feed dispenser gate
Real Time Clock DS3231	Keeps accurate feeding schedule time
LCD Display 20x4	Local display of system status
Power Supply	Main source of electricity
Solar Panel	Energy source
Battery	Store energy
Electric Motor	Give mechanical energy to the aerator
Aerating Wheel	Oxygenate pond with water circulation and splashes

Figure 1 shows the context diagram of the Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring using Hybrid Rule-Based Scheduling and Threshold Control Algorithm. The farmer is the main input entity to provide water parameter data and the feeding schedule to the system, while receiving worker reports from the system. The admin is the management entity who provides validation data and configuration data to the system and gets system reports from the system.

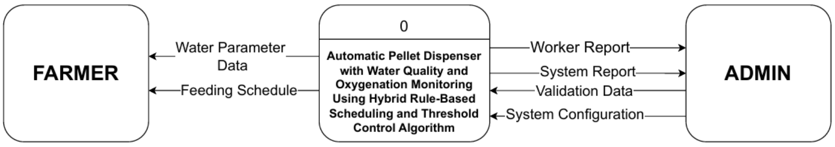

Figure 1: Context Diagram Level 0

Data Flow Diagram

Figure 2 shows the DFD (Data Flow Diagram) of the automatic pellet dispenser with
water quality and oxygen monitoring using hybrid rule-based scheduling and
threshold control algorithm is presented above. This diagram shows the data flow
and how it moves within the system. The farmers provide their data on ponds with respect to water quality, oxygen level, and feeding, and this information will be used during monitoring. Such data will then be saved in the sensor data store. Data validation and calibration will take place before it can
enter the system. After which, decision making will be done by considering the validated data and current pond status to feed and aerate the pond properly.

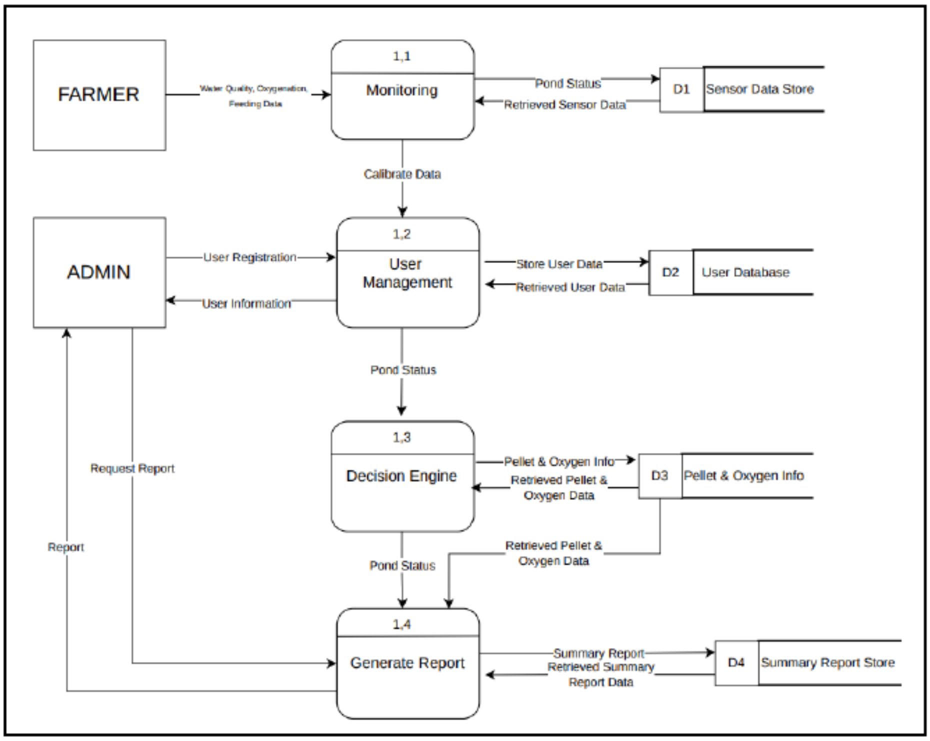

Figure 2: Data Flow Diagram (DFD) level 1

Hardware Flowchart

The analysis of pond operations was performed to determine the hardware requirements of the system. The specified hardware flow of the system encompasses the continuous acquisition of data from six water quality parameters, decision-making based on threshold values to activate the aerator, the execution of feeding schedule automation, and the presentation of data on LCD with database storage. The above relationships can be visually represented through the hardware flowchart of the system.

Figure 3 illustrates the hardware flowchart of the Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring System. After initializing all the hardware components, the system collects data from six different sensors: water temperature, TDS, water level, pH, dissolved oxygen, and ultrasonic sensors. All readings are checked against the optimal threshold values. When all parameters are within the specified limits, the system displays data on LCD and saves it in the database. However, when at least one parameter exceeds its optimal value, the system starts with the aerator motor, forms a unified alert message, and sends an SMS alert to the farmer.

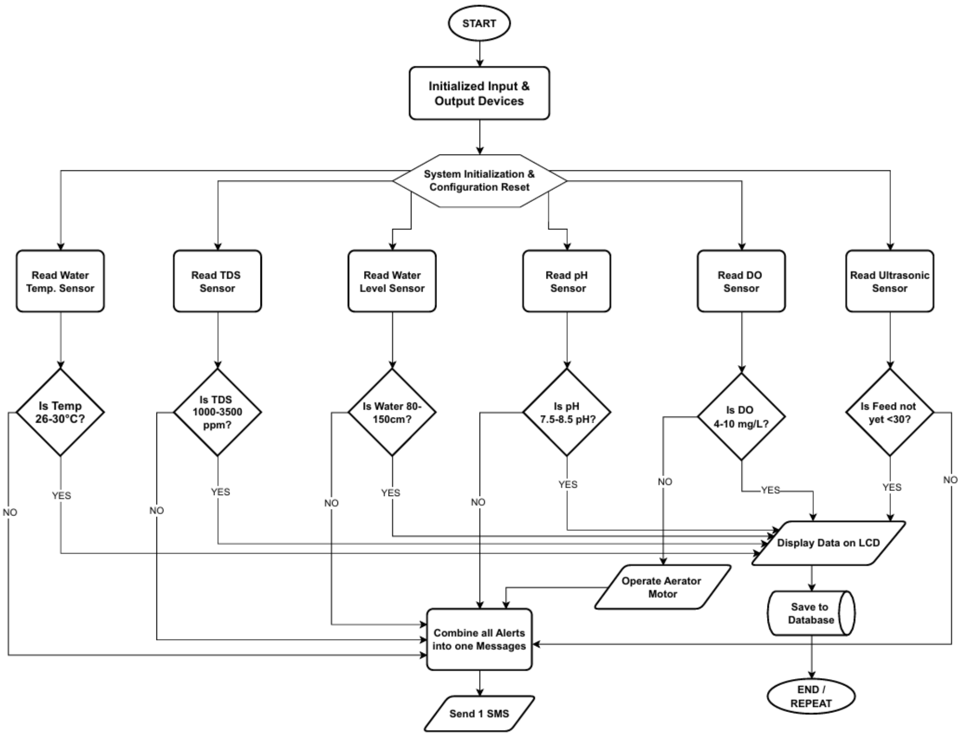

Figure 3: Hardware Flowchart

System Algorithm

The algorithm consists of two main algorithms acting together. The first algorithm is called the Hybrid Rule-Based Scheduling Algorithm, and it deals with scheduling feeding by releasing pellets from the pellet feeder according to some daily rules pre-set by the system. This is accomplished using the RTC chip (DS3231) located on the Heltec board. Table 2 shows the default feeding schedule.

Table 2: Feeding Schedule

Feeding Time
7:00 am
10:00 am
1:00 pm
4:00 pm
7:00 pm

The Threshold Control Algorithm keeps on analyzing data from sensors and initiating control actions where necessary when the parameters are outside the threshold values. The algorithm is implemented in the Heltec controller for instantaneous analysis and action, with alerts sent via SMS. Optimal values and actions are detailed in Table 3.

Respondents and Testing Procedure

The respondents were 15 farmers of shrimps from ZKD Farm who had sufficient knowledge of aquaculture processes. The testing process was divided into five stages: (1) testing the functioning of all components separately on both the controllers; (2) testing in an actual pond setting to determine the accuracy of the feeding timing, accuracy of sensors against manual testing kits, and oxygenating capacity; (3) testing the range of LoRa connectivity between the Heltec field controller and Raspberry Pi gateway; (4) testing for reliability under

Table 3: Water Quality Thresholds and Actions

Parameters	Optimal Range	Critical	System Action
Dissolved Oxygen	4.0-10.0 mg/L	<4.0 mg/L	Activate aerator via relay and Send SMS
pH level	7.5-8.5 pH	<7.5 pH	Send alert by SMS
Water Temperature	26-32 °C	<26°C	Send alert by SMS
TDS	1,000-35,000 ppm	<1,000 ppm	Send alert by SMS
Water level	80-150 cm	<80 cm	Send alert by SMS
optimal range	30-100 %	<30 %	Send alert by SMS

continuous usage with solar energy and battery-powered systems; and (5) testing the user experience with the farmer-users providing feedback using a five-point Likert scale questionnaire.

Statistical Treatment

Analysis of data utilized descriptive statistics in terms of the weighted mean. Five-point Likert scale was applied based on the interpretation provided below:

4.20-5.00 – Strongly Agree
3.40-4.19 – Agree
2.60-3.39 – Neutral
1.80-2.59 – Disagree
1.00-1.79 – Strongly Disagree

RESULTS AND DISCUSSION

The following discussions highlight the results obtained after evaluating the Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring System through 15 shrimp farmer respondents from ZKD Farm. The findings of functionality are displayed in Table 4 below. For the dimension of functionality, the average score is 4.34 and it translates to a rating of Strongly Agree. LCD display got the best score at 4.73, followed by automatic oxygenation system at 4.66. Water quality sensors were scored 4.40. Responsiveness to threshold and schedule operations got the lowest score at 3.73. This is slightly lower and it falls in the Agree category. It means there may be some minor delay that can be minimized through optimizing the control algorithm. Rivera *et al.,* (2021) observed the same for threshold-based systems.

Table 5 shows the outcomes from the Accuracy aspect. On average, the accuracy value is 4.18, which means it is interpreted as Agree. Oxygenation control with real values of dissolved oxygen had the highest score of 4.73, hence proving that the dissolved oxygen sensor and relay algorithm are accurate. The sensor readings for the other variables were also highly accurate since the mean was 4.33. However, Data Logging Consistency scored only 3.93 and Decision Synchronization scored 3.86, showing that there is a disparity in accuracy and data consistency that needs to be resolved by improving the LoRa communication.

The findings on the effectiveness dimension are illustrated in Table 6 below. Effectiveness had the highest mean score of 4.77, considered to be "Strongly Agree," which can be attributed to being the strongest aspect of the system. The automated process of oxygenation is better than the manual process with a mean score of 4.86. Farm management and productivity are enhanced by the system, receiving a mean score of 4.80, while the healthy cultivation of shrimps is ensured by monitoring the quality of water, scoring a mean of 4.80. The saving of manual effort was rated with a mean score of 4.66, agreeing with the findings of Balaji *et al.,* (2025).

Results for reliability dimension are provided in Table 7. The average score for reliability was 4.08, which means that users agreed about its quality. Solar-powered auxiliary system had the highest average value (4.66), providing continuous operation during power outage on the grid. Motor and sensor performance received the same average score (4.00), as well as prolonged operation. LoRa communication between Heltec and Raspberry Pi was checked, and it proved to be reliable over distances not exceeding 500 meters, which covers the whole area of the farm. The relatively low values received by operational consistency (3.93) and error frequency (3.80) confirm that although the system was highly reliable, some problems might arise due to environmental fluctuations, as suggested by Valerio *et al.,* (2023).

Results for the hardware dimension are summarized in Table 8. For hardware, the overall average score was 4.10, meaning that respondents agreed. The protective housing received high ratings with an average of 4.33, which proved that the system had been designed to protect its electronic components against moisture, heat, and dirt. Scores for hardware integration efficiency and suitability of physical size were 4.10 and 4.06, respectively. Average scores for dispensing and wiring organization were 4.00. This shows that the device performed well, although there is still room for improvement in terms of mechanics and organization.

The evaluation summary for all five dimensions is reflected in Table 9 below. An overall weighted mean score of 4.29, which translates to Strongly Agree, suggests that the system of Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring System is indeed highly functional, accurate, effective, reliable, and efficient. Effectiveness proved to be the main strength of the system, as it clearly demonstrates the value proposition of the product through automation, water quality control, and oxygenation using dual controllers with LoRaWAN and Raspberry Pi.

Table 4: Functionality Evaluation Results

Functionality	Mean	Interpretation
The automatic pellet dispenser is also smooth and releases the right quantity of feed.	4.2	Strongly Agree
The water quality sensors (temperature, pH, TDS, DO, water level) give reliable and congruent measurements.	4.4	Strongly Agree
When the dissolved oxygen is below the set level, the oxygenation system begins operating automatically.	4.66	Strongly Agree
The interface and the display LCD are simple to read and comprehend.	4.73	Strongly Agree
The system is responsive to scheduled and threshold-like operations.	3.73	Agree
Total Mean	4.34	Strongly Agree

Table 5: Accuracy Evaluation Results

Accuracy	Mean	Interpretation
The system pours out the pellets in the right manner according to the programmed schedule.	4.06	Agree
The sensors can give correct values based on the water quality, such as pH, turbidity, and temperature.	4.33	Strongly Agree
Oxygenation control is switched to the appropriate position, and it depends on the real dissolved oxygen levels.	4.73	Strongly Agree
The periodic information is collected in the system without delays and inconsistencies and is recorded correctly.	3.93	Agree
The decisions made by the computer are synchronized and perfectly agree with the current conditions of the pond: feeding, monitoring, and oxygenation.	3.86	Agree
Total Mean	4.18	Agree

Table 6: Effectiveness Evaluation Results

Effectiveness	Mean	Interpretation
The system assists in minimizing the manual effort in the feeding and monitoring activities.	4.66	Strongly Agree
The pellet feeding schedule is very efficient in shrimp feeding.	4.73	Strongly Agree
The water quality monitoring functions help in having a healthy culture of shrimps	4.8	Strongly Agree
The automated oxygenation is effective in terms of enhancing the conditions of ponds better than the manual methods.	4.86	Strongly Agree
The system improves management and general productivity of the farms.	4.8	Strongly Agree
Total Mean	4.77	Strongly Agree

Table 7: Reliability Evaluation Result

Reliability	Mean	Interpretation
The system works invariance under varying conditions of operation.	3.93	Agree
Solar panel and battery power sources are adequate to furnish the constant power.	4.66	Strongly Agree
The motors and the sensors are stable and can be used over a long period.	4	Agree
There are few errors or malfunctions witnessed in the system as it operates.	3.8	Agree
The system continues to operate reliably even during extended periods of continuous use.	4	Agree
Total Mean	4.08	Agree

Table 8: Hardware Evaluation Results

Hardware	Mean	Interpretation
The pellet dispensing mechanism operates smoothly without mechanical obstruction.	4	Agree
The wiring layout and hardware connections are organized, secure, and safe for long-term operation.	4	Agree
The integration of hardware components such as sensors, motors, solar panels, and battery is efficient and functional.	4.1	Agree
The size, weight, and physical layout of the system are appropriate for actual shrimp pond deployment.	4.06	Agree
The enclosure/housing protects the internal components (electronics, motors) from outdoor elements like rain, heat, and dust.	4.33	Strongly Agree
Total Mean	4.10	Agree

Table 9: Overall Evaluation Summary

Dimension	Weighted Mean	Interpretation
Functionality	4.34	Strongly Agree
Accuracy	4.18	Agree
Effectiveness	4.77	Strongly Agree
Reliability	4.08	Agree
Hardware	4.10	Agree
Total Weighted Mean	4.29	Strongly Agree

CONCLUSION

In this study, a successful design and development of an automatic feeder system combined with water quality and oxygenation monitoring were accomplished with the implementation of a hybrid rule-based scheduling and threshold control algorithm through a dual controller setup. The Heltec WiFi LoRa 32 V3 acts as the field controller for the acquisition of data and control of sensors while Raspberry Pi 4 was used as the web server for monitoring purposes. The system can automate the process of feeding, continuously monitor five important water parameters such as temperature, pH, total dissolved solids, dissolved oxygen, and water level. It also uses the real-time data provided by sensors to control the aeration of the water through the process of controlling the water pump. The LoRaWAN technology made it possible to transmit data remotely from the location of the pond to the monitoring dashboard that operates using Raspberry Pi. The evaluation by fifteen shrimp farmers at ZKD farm in Kiamba, Sarangani Province resulted in a weighted mean rating of 4.29 on a five-point Likert scale, implying Strongly Agree. The inclusion of a solar backup power system was very reliable, making sure there was smooth continuity of the process in case of any interruptions in the grid power supply. With the development of the web monitoring system on the Raspberry Pi, the farmers were able to access the sensor information, trends and notifications from remote locations. Even though the system is working efficiently, slight adjustments need to be made on the response time and synchronization of the sensor data into automation processes. In addition, the implemented dual-control system is both efficient and sustainable for the small shrimp farms, making contributions towards sustainable aquaculture.

Recommendations

The results of the Automatic Pellet Dispenser with Water Quality and Oxygenation Monitoring Using Hybrid Rule-Based Scheduling and Threshold Control Algorithm, the following recommendations are suggested: Future researchers can create an application that would allow farmers to receive notifications about water quality and control the feeding process through their phones. Future researchers could include other sensors in the system that will detect other parameters like ammonia or salinity, thus giving a full picture of the water quality.

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